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# SHARING BETWEEN THE FIXED SERVICE AND THE RADIO ASTRONOMY SERVICE IN THE FREQUENCY RANGE 3.4 GHz - 105 GHz

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## 1. INTRODUCTION

This report provides guidance on sharing between the radio astronomy and fixed services operating in the frequency range 3.4 GHz - 105 GHz within Europe. The information presented has been taken from the following sources:

- draft extracts from the ITU-R Working Party 7D radio astronomy Handbook
- information supplied by the European Science Foundation Committee on radio astronomy frequencies (ESF-CRAF)
- a working party established to study sharing aspects between the Fixed and radio astronomy services in one European country

Annex I to this report provides a list of radio astronomy frequencies which are used at the various observatories in Europe.

## 2. SHARING CONSIDERATIONS

Most radio astronomy bands are shared with active services which transmit. Such sharing is particularly difficult for radio astronomy, which is a passive service. Because of the great distances of astronomical sources the power flux density levels of the emissions under investigation are often 100 dB or more below those of man-made transmissions near the radio observatory. The strength and characteristics of the astronomical signals are determined by laws of nature and are beyond the control of the radio astronomer. Furthermore, because of the experimental nature of the science the radio astronomer is often unable to know in advance what the characteristics of the emissions will be. These factors make radio astronomy particularly vulnerable to interference. Interference can be damaging not only if it is strong and obliterates the astronomical signals, but also if it is weak. An insidious danger to radio astronomy lies in the interference which is just below the power level at which it can be recognised in individual measurements and which is present for a large fraction of the total time. In this case there may be no means during the experiment of detecting that interference has occurred, and subsequent data examination could lead to serious errors.

Radio astronomy observatories are usually located at sites specially chosen to minimise interference from other services. The sites are usually at a considerable distance from the major terrestrial sources of interference and are frequently screened by nearby high ground. With this protection for the observatory and the protection afforded by the curvature of the Earth, sharing with terrestrial transmitters is possible when the transmitter power is low and there is sufficient geographical separation. However, with the very sensitive systems used in radio astronomy, large separations are usually necessary. Sharing is not generally possible when the transmitter is within line-of-sight of the radio astronomy antenna or the antenna feed. It is usually necessary for the transmitter to lie well over the horizon, at distances of 100 km or more.

## 3. PROTECTION CRITERIA FOR THE RADIO ASTRONOMY SERVICE

An important protection criterion for radio astronomy is the power level of the interference considered harmful. The harmful threshold depends on the frequency of observation and the type of measurement being made. Threshold interference levels for both continuum and spectral line observations are presented in Recommendation ITU-R RA.769.

A second criterion relates to the fraction of the sky for which radio astronomy observations are to be protected. For ground-based sources of interference a value of 0 dBi is adopted for the gain of the radio astronomy antenna in the direction of the interfering source, or in the direction of the horizon for a distant transmitter. The adoption of this value means that potential sources of interference at the harmful threshold levels given in Recommendation ITU-R RA.769 will not cause harmful interference to observations made at elevation angles greater than 19 degrees (based on the generalised radiation pattern given in Recommendation ITU-R SA.509). In fact radio astronomers may be prepared to accept this restriction of their sky coverage, provided that earth-rotation allows all available parts of the celestial sphere to be accessed at some time.

A third criterion which must be considered is the percentage of time that a harmful interference level may be exceeded without seriously degrading the operation of the service. In this report a single percentage value has been chosen for all cases although it is clear that some observations are more susceptible to brief periods of interference than others. For the calculations presented in this report it has been accepted that the harmful interference levels given in Recommendation ITU-R RA.769 may be exceeded due to propagation effects for no more than 10 % of the time. Strong interference occurring only 10 % of the time because transmissions are limited to that period of time would not be acceptable. It should be noted that the detailed characteristics of the interference and their relation to the particular type of radio astronomical observation will need to be taken into account.

It must be emphasised that for some types of observation a 10 % failure rate due to interference imposes severe restrictions on the radio astronomer. For some observations a high probability of success is desirable because of the difficulty or impossibility of repeating them. An example is an observation of a comet, which may produce rapidly varying emissions during its passage, and which may not return for many hundreds of years. Some other types of observation require simultaneous measurements at different wavelengths and at a number of sites, at each of which success must be obtained if the experiment as a whole is to be successful. An example is a co-ordinated multi-wavelength study of a flaring nova. The experiment may be severely damaged if observations at any one of the observatories are ruined due to interference. An observatory having difficulties of this type will require special national arrangements at certain frequencies at certain times.

Another propagation effect to consider is reflection of the interfering signal. Reflections from aircraft are likely causes of harmful interference in a shared band even when the terrestrial transmitter is distant. The possibility of interference by reflection from low-orbit satellites also exists. A single reflecting body will be effective for a short time; the interference problem will depend on the density of air or space traffic. A problem is that as a result of space activities there are a large number of metallic objects in orbit around the Earth. For certain types of radio astronomical measurement in shared bands, reflections of terrestrial transmissions by the Moon can cause serious interference.

The three protection criteria so far considered, the power threshold of harmful interference, the percentage of sky which is to be protected and the fraction of observing time which is to be protected, all relate directly to geographical sharing; that is, the geographical spacing of two services which permits both to work at the same frequency at the same time. In sharing between some services additional protection may be obtained by the use of orthogonal polarisations. This is not a useful technique for protecting radio astronomy since different polarisations must be used for some observations, and since the interference generally enters the radio astronomy system through far sidelobes whose polarisation characteristics are very different from those of the main beam.

Limited time sharing to permit special observations at a radio astronomy site may be possible, and may indeed be necessary on occasion, as discussed in section 5.

# 4. COORDINATION DISTANCES REQUIRED FOR SHARING

If geographical sharing is to be successful the interfering transmitter and the interfered-with receiver must be separated by a distance at which the interference is not considered harmful. The attenuation over this distance must be sufficient to reduce the received signal below the appropriate level of Table 1, 2 or 3 of Recommendation ITU-R RA.769, for all but 10 % of the time. Appendix 28 of the Radio Regulations defines a basic transmission loss $L_b(p)$ as:

$$L_b(p) = P_t + G_t + G_r - P_r(p) \qquad (1)$$

where:

- $L_b(p)$: minimum permissible basic transmission loss (in dB) for p % of the time; this value must be exceeded by the actual transmission loss for all but p % of the time;
- $P_t$: transmitting power level (in dBW) in the reference bandwidth at the input to the antenna;
- $G_t$: gain (in dBi) of the transmitting antenna;
- $G_r$: gain (in dBi) of the receiving antenna in the direction of the transmitter;
- $P_r(p)$: maximum permissible interference power (in dBW) in the reference bandwidth to be exceeded for no more than p % of time at the receiver input.

Since $G_r$ = 0 dBi, equation (1) assumes the form:

$$L_b(p) = P_t + G_t - P_r(p) \qquad (2)$$

where $P_r$ is to be taken from column 7 of Table 1 or Table 2 of Recommendation ITU-R RA.769. $L_b(p)$ should be calculated using an appropriate model, such as those contained in Recommendation ITU-R PN.452, using p = 10 % in the case of time-variable propagation loss.

In the above analysis $P_t$ is the power transmitted by the active service within the bandwidth Br of the radio astronomy receiver. If the transmitter power $P_T$ is distributed over a bandwidth $B_t > B_r$ then:

$$P_t(\text{dBW}) = P_T(\text{dBW}) - 10\log(B_t/B_r) \qquad (3)$$

assuming that the transmitter power has a uniform spectral density.

## 4.1. Sharing within line-of-sight

It is rarely possible for radio astronomy to share successfully with any other service whose transmitters are within line-of-sight of the observatory. Recommendation ITU-R PN.452 contains a procedure for calculating the line-of-sight propagation loss (including short-term enhancements). Using this procedure, even at frequencies as high as 50 GHz, results in co-ordination distances which place the transmitter well over the horizon. In order for sharing to be possible within line-of-sight, either the transmitter power must be of the order a few milliwatts or the transmitting antenna must provide high discrimination in the direction of the observatory.

## 4.2. Sharing beyond the horizon

The establishment of co-ordination zones around radio astronomy sites provides a method of avoiding harmful interference from active terrestrial services which share a radio astronomy band. From the preceding discussion it is clear that sharing will normally only be possible for terrestrial services beyond the horizon. The basic criterion used to define a co-ordination zone is that the total interference from all users outside the zone must not exceed the harmful interference level measured at the radio astronomy site. Thus the size of the co-ordination zone depends on a number of factors:

i) the type of measurements being made at a particular radio astronomy site (these determine the corresponding harmful interference thresholds given in Recommendation ITU-R RA.769);

ii) the number and distribution of the transmitters;

iii) the transmitter e.i.r.p. in the direction of the radio astronomy site;

iv) the fraction of the time the transmitter is active;

v) the profile of the terrain;

vi) the local presence of trees/buildings;

vii) atmospheric conditions.

Because of the many factors involved the boundaries of the co-ordination zones need to be established individually for each radio astronomy site at which such a zone is required, taking due account of any special features of the radio astronomy measurements and of the active service which shares the band. It should be realised that the size of the co-ordination zone could be a hundred kilometres or more. For many small countries the co-ordination zone required may extend beyond the national boundaries into countries where the frequency allocations may be different. Thus special conditions may need to be applied when determining co-ordination zones to protect radio astronomy in small countries.

The co-ordination zone defines a region around the radio observatory outside of which the users of the active service can transmit freely without causing harmful interference to the radio astronomy observations. For users within the co-ordination zone some means must be found to avoid harmful interference to the radio astronomy service, for example by pointing the Fixed link away from the observatory or taking advantage of natural shielding.

### 4.3. Sharing in the band 3.4 GHz - 50 GHz

This section describes the results of sharing calculations which have been carried out for shared radio astronomy bands below 50 GHz. Co-ordination distances have been calculated between a hypothetical transmitter and radio astronomy receiver.

For a time percentage of 10 % and distances greater than approximately 100 km, the tropospheric scatter mechanism is dominant. For shorter distances diffraction dominates. Recommendation ITU-R PN.452-5 provides procedures for evaluating the available propagation loss between stations on the surface of the Earth within the frequency range of about 0.7 GHz to 30 GHz.

Table 1 presents co-ordination distances which have been calculated to the nearest 5 km, using the tropospheric scatter prediction procedure provided in this Recommendation. In the absence of an alternative approach within Study Group 3 documentation, this predication procedure has been used for frequencies up to 50 GHz. Results are given for three sites having horizon angles of 0°, 1° and 4° respectively.

In some cases the transmitter bandwidth is less than the receiver bandwidth and hence a number of transmitting channels within the receiver bandwidth can be occupied. For the purposes of producing Table 1 it has been assumed that at a specific distance from the observatory, only one transmitter is pointing in the direction of the observatory and operating within the receiver bandwidth.

For co-ordination distances less than 100 km the dominant propagation mechanism is diffraction rather than tropospheric scatter and hence a detailed knowledge of the terrain is required to calculate the co-ordination distance.

The column description in Table 1 are as follows:

Column

(1) the frequency of the radio astronomy band;

(2) transmitter power;

(3) gain of the transmitter in the direction of the radio astronomy observatory;

(4) transmitter e.i.r.p. in the direction of the radio astronomy observatory;

(5) transmitter bandwidth;

(6) the type of radio astronomy observation (C denotes continuum and SL denotes spectral line observations);

(7) threshold for harmful interference, taken from column 7 of Tables 1 and 2 of Recommendation ITU-R RA.769, for continuum and spectral line observations respectively;

(8) radio astronomy bandwidth used in the calculation;

(9) the required transmission loss calculated using equations (2) and (3);

(10) co-ordination distance required to avoid harmful interference to the radio astronomy observations in the case where the horizon at the observatory is at an elevation angle of 0 degree;

(11) co-ordination distance required to avoid harmful interference to the radio astronomy observations in the case where the horizon at the observatory is at an elevation angle of 1 degree;

(12) co-ordination distance required to avoid harmful interference to the radio astronomy observations in the case where the horizon at the observatory is at an elevation angle of 4 degrees.

**TABLE 1 - Sharing parameters and Co-ordination distances**

| **Frequency** | **Assumed interfering transmitter** | | | | **Assumed radio astronomy receiver** | | | **Required transmission loss** | **Co-ordination Distance** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | d(0°) | d(1°) | d(4°) |
| MHz | $P_t$ dBW | Gt dBi | e.i.r.p. dBW | $B_t$ MHz | C/SL | $P_r$ dBW | $B_r$ MHz | L dB | km | km | km |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| 4830 | 10 | 44 | 54 | 40 | SL | -218 | 0.05 | 243 | 520 | 410 | 135 |
| | 10 | 0 | 10 | 40 | SL | -218 | 0.05 | 199 | 110 | <100 | <100 |
| 5000 | 10 | 44 | 54 | 40 | C | -207 | 10 | 255 | 650 | 535 | 230 |
| | 10 | 0 | 10 | 40 | C | -207 | 10 | 211 | 195 | 120 | <100 |
| 10600 | 7 | 44 | 51 | 100 | C | -202 | 100 | 253 | 535 | 430 | 155 |
| | 7 | 0 | 7 | 100 | C | -202 | 100 | 209 | 130 | <100 | <100 |
| 22200 | -7 | 45 | 38 | 50 | SL | -210 | 0.25 | 225 | 130 | <100 | <100 |
| 31000 | -10 | 45 | 35 | 100 | C | -192 | 500 | 227 | 150 | <100 | <100 |
| 49000 | -17 | 40 | 23 | 7 | SL | -207 | 0.50 | 219 | <100 | <100 | <100 |

### 4.4. Sharing in radio astronomy bands above 50 GHz

There are allocations above 50 GHz to the radio astronomy service for both continuum and spectral line observations. Some of these allocations are shared with a variety of active services. Until recently there have been relatively few active systems operating above 50 GHz, and consequently few reported cases of interference to radio astronomy. Sharing with active services above 50 GHz will be made easier by several facts:

i) high transmitter gains are easier to achieve with antennas of modest size;

ii) atmospheric attenuation is higher;

iii) the tropospheric scatter signal decreases monotonically with increasing frequency.

## 5. TIME SHARING

Because of the nature of the phenomena observed in radio astronomy, only under special conditions will it be feasible to devise time-sharing programmes between radio astronomy and other services. Furthermore active users who provide a service to customers may be unwilling or unable to adopt time sharing. Time sharing may sometimes be possible in principle, but in practice the difficulties associated with it are operational rather than technical. For these and other reasons time sharing has not yet been a feature of any extended radio astronomy programme.

Nevertheless limited time sharing to permit observations at a radio astronomy site may be possible, and may indeed be necessary on occasion. Radio astronomers sometimes need to observe outside the frequency bands allocated to their service, and in such cases time sharing with active services may be the only available option. Recommendation ITU-R RA.314-8 acknowledges this fact, and urges administrations to provide assistance in the co-ordination of experimental observations of spectral lines in bands not allocated to radio astronomy.

## 6. GUIDANCE ON ESTABLISHING COORDINATION ZONES LESS THAN 100 km

Table 1 shows that in the cases where the fixed link has a low e.i.r.p. or the frequency is sufficiently high, the co-ordination distance is often less than 100 km. Therefore the co-ordination zone should be determined using an appropriate diffraction model. In order to calculate diffraction loss accurately a detailed knowledge of the terrain is required for each azimuth around the radio observatory and hence it may be useful to computerise the procedure. In the absence of detailed terrain knowledge, a co-ordination zone can be established based upon practical sharing experience. The following sections provide guidance on establishing co-ordination zones based upon the practical sharing experiences of one European country.

### 6.1. Practical experience of sharing at 22 GHz

Within one European country, the radio astronomy and fixed services have successfully shared the bands 22.21 - 22.5, 22.81- 22.86 and 23.07 - 23.12 since 1988. A co-ordination zone with a radius of 50 km has been in operation and both services have agreed that this arrangement has been successful. Typical parameters for the fixed service in this band are: Power -15 dBW, Gain 41.5 dBi, Bandwidth 3.5 MHz. The radio astronomy observatories in this country have horizon angles of approximately 1 degree.

## 6.2. Sharing at 10 GHz

The radio astronomy and fixed services have a shared allocation in the band 10.6 - 10.68 GHz. Table 1 shows that at 10 GHz, the co-ordination distance can be less than 100 km if the e.i.r.p. is sufficiently low and there is a sufficient horizon angle at the observatory. Within one European country a TDMA Point to Multipoint system is in operation. This system has the following parameters:

**TABLE 2**

| | Base station | Outstation |
|---|---|---|
| **Power (dBW)** | **-6** | **-11** |
| **Gain (dBi)** | **13** | **34** |
| **Bandwidth (MHz)** | **2** | **2** |

Compared with the situation at 22 GHz, both the propagation loss and the required transmission loss are less at 10 GHz. Hence in order to calculate an appropriate co-ordination distance it is necessary to carefully compare the frequency dependent terms used to calculate propagation loss and the required transmission loss for the two bands. The outstation has the higher e.i.r.p. and hence has been used in the following table:

**TABLE 3**

| Frequency (GHz) | Required transmission loss (dB) | Frequency dependent terms used in propagation calculations | |
|---|---|---|---|
| | | 20logf (dB) | Gaseous absorption at 50 km (dB) |
| **10.6** | **200** | **20.5** | **0.5** |
| **22.2** | **225** | **27.0** | **4.1** |

The table shows that at 10 GHz the lower required transmission loss more than compensates for the smaller propagation factors. Hence a co-ordination distance of 50 km should work equally well at 10 GHz for this low power Point to Multipoint system operating in this country and in most other European countries depending on the local terrain around the radio observatories.

## 6.3. Sharing in the 31 GHz, 43 GHz and 49 GHz bands

The radio astronomy and fixed services have shared allocations in the bands 31.5 GHz - 31.8 GHz, 42.5 GHz - 43.5 GHz and 48.94 GHz - 49.04 GHz. There has been no practical experience of sharing in these bands within Europe in the past. The propagation loss at these frequencies should be higher than at 22 GHz. Hence, unless e.i.r.p. and/or traffic densities of the fixed service substantially exceed the levels for the 22 GHz case, a co-ordination zone with a 50 km radius should be suitable to protect the radio astronomy service in most European countries depending on the local terrain around a radio observatory.

# ANNEX I

## FREQUENCY BANDS CURRENTLY USED BY THE RADIO ASTRONOMY SERVICE IN EUROPE IN THE FREQUENCY RANGE 3.4 GHz - 105 GHz

The following table provides an indication as to which countries in Europe are currently utilising particular radio astronomy bands. The table has been supplied by ESF-CRAF and has been updated by information provided by CEPT SE19 members in March 1995. It should be noted that some of the bands or parts of the bands listed in the table may not be allocated or protected in all the countries indicated.

**TABLE 4**

| FREQUENCY GHz | STATUS IN DSI | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.80 - 4.99 | secondary | D | | | F | GB | | NL | P | S |
| 4.99 - 5.00 | primary | D | | | F | GB | I | NL | P | S |
| 8.387 - 8.443 | - | D | E | | F | | I | | | S |
| 9.60 - 9.62 | - | | E | | F | | | | | |
| 9.70 - 10.60 | - | | | | | GB | | | | |
| 10.60 - 10.68 | primary | D | | | | GB | | | | |
| 10.68 - 10.70 | primary | D | | | | GB | I | | | |
| 14.47 - 14.50 | secondary | D | | | | GB | | | | |
| 14.50 - 15.35 | secondary | D | | | | GB | | | | |
| 15.35 - 15.40 | primary | D | | | | GB | I | | | |
| 22.01 - 22.21 | primary | D | | | | | | | | S |
| 22.21 - 22.50 | primary | D | E | FI | | GB | I | | | S |
| 22.81 - 22.86 | primary | D | | | | GB | | | | S |
| 23.07 - 23.12 | (RR879) | D | | | | GB | | | | S |
| 23.60 - 24.00 | primary | D | E | | | GB | I | | | S |
| 31.30 - 31.50 | primary | D | E | | | GB | | | | S |
| 31.50 - 31.80 | primary | D | E | | | GB | | | | S |
| 42.50 - 43.50 | primary | D | E | FI | | | I | | | S |
| 48.94 - 49.04 | primary | D | E | | | | | | | |
| 85 - 105 | various | D | E | FI | F | | | | | S |

Country key:

D Germany
E Spain
FI Finland
F France
GB Great Britain (UK)
NL Netherlands
P Poland